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Cone Production of Western White Pine Seedlings and Grafts

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ABSTRACT

Grafts of western white pine planted in a seed orchard within the white pine type produced 6 cones per tree 11 years after grafting; grafts of the same families in a breeding arboretum located on a grassland habitat produced 1.6 cones per tree 14 years after grafting. Seedlings in the breeding arboretum produced 1.2 cones per tree at 12 years of age. Placement of seed orchards of western white pine is discussed.

KEYWORDS: cone production, seed orchards, western white pine.

The final efforts of tree improvement is to produce seed of improved varieties. Most forest tree species will produce more seed sooner on particular sites (Falconer 1975), and grafts usually produce before seedlings.

After choosing a species to improve, tree breeders should immediately begin to plan seed orchard locations and to decide whether to vegetatively propagate parent trees or to use seedlings. Failure to do so may mean delays in seed production.

Records of cone production of western white pine in the inland portion of its range have been gathered for many years, and some data have been published (Bingham and Squillace 1957; Barnes and others 1962; Barnes and Bingham 1963; Barnes 1969; Bingham and Rehfeldt 1970; Rehfeldt and others 1971; Bordelon 1978; Hoff[2]). This note summarizes data on cone production for grafts of mature trees growing at two locations and for seedlings at one location.

MATERIALS AND METHODS

Cone production data were collected from western white pine growing at two different sites in northern Idaho. One site is located near Moscow, Idaho, and is called the Moscow Arboretum. The second site is near Sandpoint, Idaho, and is called the Sandpoint Seed Orchard.

The Moscow Arboretum site is part of the Palouse prairie, an *Agropyron spicatum:Festuca idahoensis* habitat type. The average frost-free period is 123 days and average annual precipitation is 508 mm (20 inches). The arboretum was irrigated from 1958 to 1968. The seed orchard at Sandpoint is located within a typical white pine site, a *Tsuga heterophylla:Pachistima myrisinites* habitat type. Its average frost-free period is 121 days and average precipitation is 762 mm (30 inches).

Moscow Arboretum contains grafts of phenotypically resistant western white pine from native stands and seedlings of two parent crosses of phenotypically resistant trees. The 44 grafts are from 22 clones with 1 to 4 ramets per clone. Seedlings come from 509 families with 1 to 20 individuals per family and total 1,356.

The grafts were made in a greenhouse in 1951-52 and grown in a lathhouse until planted in the arboretum in 1958. The seedlings were survivors from several progeny tests for selecting white pine seedlings resistant to blister rust. Although the progeny tests spanned several years, they were planted into the arboretum in two basic groups. Therefore, this paper will treat the seedlings as the "old trees" (seedlings from the 1952, 1953, 1954, and 1955 progeny tests) and the "young trees" (seedlings from the 1961, 1962, and 1963 progeny tests).

Seedlings of the 1952-55 progeny test were sown in 5-cm x 5-cm x 20-cm (2-inch by 2-inch by 8-inch) containers in a nursery near Spokane, Wash. The seedlings were artificially inoculated with white pine blister rust in September following their second growth period. They were then outplanted into a natural forest area where they received natural exposure to blister rust. The most resistant seedlings from each family were lifted and planted into the arboretum from 1958 to 1961.

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[2]Hoff, R. J. 1978. Mountain pine cone beetle damage in the Sandpoint Seed Orchard. *In* Progress Report, Inland Empire Cooperative Forest Tree Improvement Program. p. 37-40. Intermt. For. and Range Exp. Stn., Moscow, Idaho.

Seed of the 1961-63 progeny test was sown in nursery beds at Moscow, Idaho. Seedlings were inoculated artificially with blister rust in September after their first growing period. The most resistant seedlings were lifted and planted in the arboretum from 1964 to 1967.

The Sandpoint Seed Orchard was established in 1960 using grafts of 13 phenotypically blister rust resistant trees in native stands. The grafts were made in a greenhouse in 1959. In 1960, there were over 100 ramets per clone. Between 1964 and 1967 one of the less resistant clones was replaced by a clone with higher resistance and four clones from high elevations were replaced by clones from low elevations. Also, incompatibility of four clones appeared in 1970; this destroyed about 75 percent of the ramets of each of four clones. By the fall of 1980 there were 811 trees left in the orchard. Only 444 original grafts (those made in 1959) remained by the fall of 1980.

For the Moscow Arboretum, cones for each individual seedling were counted from 1960 (first cones produced) through 1969 and from 1976 through 1980. Between 1970 and 1975, only the total number of cones produced was tallied. For the Sandpoint Seed Orchard, the number of cones per graft were counted from 1960 through 1969 and in 1980, and the total number harvested from 1970 to 1979.

Height of all trees in both locations was measured during the winter of 1969-80.

Data are presented as the number of cones per tree. To determine the effect of height and family on cone production in the arboretum, we used the families of the old tree group with at least three individuals per family. Cones were totaled over years. Analyses of variation, correlation, and regression were performed by least squares using the GLM Procedure contained in SAS (1979).

RESULTS AND DISCUSSION

The older tree group in the Moscow Arboretum started producing cones when they were 8 years old (table 1), but no substantial production occurred until 22 years. They were at least 24 years old (after sowing) before a "breeding population" developed (with at least 50 percent of trees producing cones and pollen). The arboretum grafts produced first cones 13 years after grafting, but did not develop a breeding population until 26 years.

The grafts at the Sandpoint Seed Orchard produced cones the first year after grafting and a breeding population developed 11 years after grafting (table 1). Actual harvest at Sandpoint for 1977 and 1978 does not reflect the cone production potential because nearly 90 percent of the cones during those two rather large cone years were lost due to insect damage.

Table 1.--Cone production of western white pine in Moscow Arboretum and Sandpoint Seed Orchard

Cone year	Moscow Arboretum				Sandpoint Seed Orchard (grafts)	
	All trees[1]	Young trees[2]	Old trees[3]	Grafts[4]	Trees[5]	Cones/tree
	Cones/tree					
1960	0.01		0.02	0	1,426	0
1961	.01		.02	0	1,054	0.003
1962	.09	0	.02	0	933	.004
1963	.01	0	.02	0	954	.01
1964	1.2	0	2.0	1.6	920	.9
1965	1.9	0	3.0	2.0	982	.1
1966	.5	0	.9	1.3	945	.2
1967	.4	0	.6	.4	1,016	.1
1968	.4	0	.5	1.4	1,200	.6
1969	3.6	0	6.1	.2	1,300	.6
1970	2.0				1,364	6.2
1971	3.9	Data not compiled by individuals for			1,340	3.7
1972	.2	these years			1,331	2.3
1973	1.4				1,331	6.0
1974	6.5				1,109	20.6
1975	7.0				954	5.2
1976	14.0	0.9	20.5	14.4	880	6.5
1977	22.4	2.3	34.5	32.7	863	2.3
1978	32.0	4.3	49.0	38.0	863	5.0
1979	2.2	1.7	2.6	1.3	811	0
1980	21.1	4.1	31.4	37.4	795	80.3

[1]These data reflect cone production for the 1,365 individuals of western white pine in the arboretum.

[2]Includes trees from the 1961, 1962, 1963, and 1964 sowings - 510 individuals.

[3]Includes trees from the 1952, 1953, 1954, and 1955 sowings - 811 individuals.

[4]Grafts of various candidate trees made in 1950 and 1952 - 43 individuals.

[5]Grafts made mainly in 1959, but some were made between 1964 and 1968.

In 1979, the average height of the older arboretum trees was 7.3 m (24 ft); the height of the grafts in the arboretum averaged 7 m (23 ft). The average height of the Sandpoint Seed Orchard grafts (made in 1959) was 9.5 m (31 ft). Table 2 compares grafts of the same clones at Moscow and at Sandpoint. Obviously, white pine grows much better at Sandpoint.

Nearly 50 percent of the variation in total cone production within the older tree group in the arboretum was due to height and family (R^2 = 0.49). For Sandpoint Seed Orchard the R^2 was 0.34. Both variables were significant (table 3). Family means adjusted for height for the arboretum varied from 31 to 239 cones per tree with a mean of 132; families in Sandpoint Seed Orchard varied from 50 to 200 with a mean of 107. The regression coefficient for height on total cones was 30.3 cones per meter (9.4 cones per foot) for the arboretum and 14.1 cones per meter (4.3 cones per foot) for Sandpoint Seed Orchard.

The Moscow Arboretum was not intended to be a seed orchard. However, the fact that the trees in the arboretum did produce cones provided the opportunity to compare it to a site that was specifically chosen as a seed orchard--the Sandpoint Seed Orchard. Although this may not be a valid comparison, it does indicate some of the limiting factors that come into play in seed production of western white pine.

The Sandpoint Seed Orchard site is obviously the better site. The trees not only produced sooner at a fairly high level but were also more vigorous, faster growing trees. The almost complete loss of 1977 and 1978 cone crops to cone insects at Sandpoint, when compared to very small losses in the Moscow Arboretum, somewhat offset these advantages. The arboretum is 8 to 9 miles from the nearest natural white pine stand; therefore, fewer insects get to the arboretum. Sanitation methods were probably more effective, also.

Several limiting factors stand out when the two sites are compared (table 4). The only similarity between the two sites was the number of frost-free days. Even here there is a timing difference. Spring is later at Sandpoint, but the frost-free period extends longer into fall. After observing the two sites over the last 20 years, I feel that one of the most important environmental factors is the difference in winter exposure. The arboretum trees suffer much wind damage, not only from breakage but also from drought stress.

Concerning the insect damage at Sandpoint, the production history of western white pine indicates that insects will pose no real problem because the species produces frequent abundant crops (Barnes and others 1962; Bingham and Rehfeldt 1970; Rehfeldt and others 1971). And in the decade from 1971 to 1980 there were only 3 years (1972, 1973, and 1974) when few cones were produced in mature stands.

The data presented in this paper seem to indicate that the best site for a white pine seed orchard is within the white pine type. It seems reasonable to expect, however, that the species will perform in a longer growing period if some of the environmental factors critical to white pine growth and production are provided or ameliorated--especially soil moisture, pH, and wind protection. Other factors not addressed in this paper that are probably important are humidity and/or air temperature. Rehfeldt (1979) showed that white pine grew much better in a site with lower temperatures and higher humidity. These requirements would not be difficult to provide with an irrigation system set up to mist the orchard at certain temperature or humidity levels.

Table 2.--Comparison of height and diameter of grafts of the Moscow Arboretum and the Sandpoint Seed Orchard

Family	Sandpoint				Moscow			
	Ramets	Height	Diameter		Ramets	Height	Diameter	
		m (ft)	*cm*	*(in)*		*m (ft)*	*cm*	*(in)*
17	89	10.4 (34)	18	(7)	2	7.0 (23)	13	(5)
19	49	8.8 (29)	15	(6)	1	3.7 (12)	8	(3)
22	88	9.5 (31)	15	(6)	3	7.0 (23)	15	(6)
24	63	9.5 (31)	15	(6)	1	4.6 (15)	13	(5)
37	33	9.5 (31)	15	(6)	1	8.5 (28)	20	(8)
58	38	10.7 (35)	15	(6)	2	7.6 (25)	13	(5)

Table 3.--Analyses of variance by least squares for the effect of height and family on cone production in Moscow Arboretum and Sandpoint Seed Orchard

Source	Moscow Arboretum[1]		Sandpoint Seed Orchard[2]	
	MS	F value	MS	F value
Family	22,749	3.14**	10,310	7.35**
Height	1,785,765	246.42**	191,843	136.77**
Error	7,247		1,403	

**Significance of value at 0.01 level of probability.
[1]Performed only for the older trees, 649 trees.
[2]Performed on the grafts made in 1959, 444 trees.

Table 4.--Factors that may reveal causes for differences of cone production between the Moscow Arboretum and the Sandpoint Seed Orchard

Factors	Moscow Arboretum	Sandpoint Seed Orchard
Frost-free period	May 12-Sept. 6 (123 days)	May 18-Sept. 16 (121 days)
Precipitation	508 mm (20 in)[1]	762 mm (30 in)
Winter exposure	Open site with much wind damage	Protected, with little or no wind damage
Soil type	Palouse loess	Mission loam
Soil acidity	pH 7.8	pH 5.9-6.5
Ecological site	Natural grassland	Typical white pine type

[1]The Arboretum was irrigated with sewage effluent from 1958 to 1968 and again in 1977 following the winter drought of 1976-77.

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